HARDWARE IMPLEMENTATION OF SOIL MOISTURE MONITORING SYSTEM

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF TECHNOLOGY IN ELECTRICAL ENGINEERING

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National Institute of Technology, Rourkela

<u>Certificate approved</u>

This is to certify that thesis titled **"*Hardware Implementation of Soil Moisture Monitoring System*",** is submitted by Biswadarshi Naik (108EE050), Pallavi Behera (108EE072) and Baijayanti Mala Das (108EE078), in partial fulfillment of the award of Bachelor of Technology in the Department of Electrical Engineering at National Institute of Technology, Rourkela and is an authentic work carried out by them under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Prof. Susmita Das

Date: 07.05.2012

Place: Department of Electrical Engineering,

National Institute of Technology, Rourkela

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Further, we would like to thank all the laboratory and administrative staff members of Department of Electrical Engineering for their humble cooperation and support. We would also take this opportunity to give thanks to all others who have helped us throughout our project and study at our institute.

Yours Sincerely,

BISWADARSHI NAIK
PALLAVI BEHERA
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ABSTRACT

Appropriate soil water level is a necessary pre-requisite for optimum plant growth. Also, water being an essential element for life sustenance, there is the necessity to avoid its undue usage. Irrigation is a dominant consumer of water. This calls for the need to regulate water supply for irrigation purposes. Fields should neither be over-irrigated nor under-irrigated. Over time, systems have been implemented towards realizing this objective of which automated processes are the most popular as they allow information to be collected at high frequency with less labor requirements. Bulk of the existing systems employ micro-processor based systems. These systems offer several technological advantages but are unaffordable, bulky, difficult to maintain and less accepted by the technologically unskilled workers in the rural scenario.

The objective of this project is to design a simple, easy to install methodology to monitor and indicate the level of soil moisture that is continuously controlled in order to achieve maximum plant growth and simultaneously optimize the available irrigation resources. A simple opamp based comparator circuit is used coupled with relay units which control the water pumps. The use of easily available components reduces the manufacturing and maintenance costs. This makes the proposed system to be an economical, appropriate and a low maintenance solution for applications, especially in rural areas and for small scale agriculturists.

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CHAPTER I: Introduction

Proper irrigation management is essential for high yields and to avoid stress from excess or scarcity of water. Determining when to irrigate is not an easy task. Usually this decision is based on past experiences, weather forecast information (crop evapo-transpiration data) or soil-related measurements. Past experiences are probabilistic and are often not adjusted for annual changes in weather. Irrigation scheduling based on crop evapo-transpiration can be difficult. This can make scheduling using weather based information uncertain. Because of the shortcomings of these methods, *soil-based* irrigation scheduling is the preferred technique.

In soil-based measurements, most commonly the *soil moisture* content is monitored.

There are different methods that are used for realizing this [2]

Feel and Appearance method using shovel or soil auger:

This method is subjective and requires experienced monitoring. Also it is imprecise.

Meters and Sensors:

Sophisticated devices like sensors measure some physical property that is related with soil moisture. Some portable sensing tools are pushed into the soil directly or into an access tube planted in the soil. Other systems rely on buried sensors that are wired to a fixed meter.

Being an automated process, this provides accurate results and is highly efficient.

Proposed Model

The objective of this project is

- To develop a *cost effective and automated model* to monitor and regulate the moisture level of a soil sample *mainly aimed* to cater *to the needs of technologically ignorant rural farmers*.
- To test the feasibility of indigenous sensors *(resistance blocks)* instead of using commercially available ones.

The heart of the system is a comparator circuit. When soil moisture level crosses a preset safety threshold which has to be maintained to protect the crops, the sensors sense the change. This signal is then sent to the relay which actuates the water pump appropriately until the strayed-out parameter has been brought back to its optimum level.

CHAPTER II: Background and Literature Review

The soil moisture varies from saturation to permanent wilting point. Various concepts related to soil moisture level are discussed below [2]

a. Readily Available Water (RAW)

By definition, the Readily Available Water (RAW) is the water that can be easily extracted by a plant from the soil. RAW is the soil moisture held in the range between field capacity and a nominated refill point for unrestricted growth. In this range of soil moisture, the soil is neither waterlogged nor water-stressed and the plants have good condition to grow.

b. Refill Point

As the quantity of water reduces due to removal by plants and by evaporation from the soil surface, it becomes increasingly difficult for plants to extract water as it clings more tightly to soil particles and in small pore spaces. When water extraction becomes difficult for plants and more water is required to maintain growth rates, the soil is said to be at the 'refill point'. The drier the soil more is the amount of water that needs to be added to bring the soil back to field capacity. Refill point for horticultural crops lies between a tension of -20 kPa and -60 kPa.

c. Permanent Wilting Point (PWP)

Further, if the soil continues to dry, it will hold some water which cannot be extracted by plant roots. As a result, plants wilt and cannot recover. This is called the Permanent Wilting Point (PWP). If the soil dries to the permanent wilting point, the plant can no longer remove any water from it. Plant production will slow/stop before PWP is reached (a tension of

-1500 kPa).

Measuring the soil moisture content allows monitoring the water available to the plant for growth. When the water at any depth falls below the refill point or where there is no remaining readily available water (RAW) then an irrigation scheduling event must be undertaken without delay.

1. SYSTEM MODEL

1.1 Basic Model Of The System

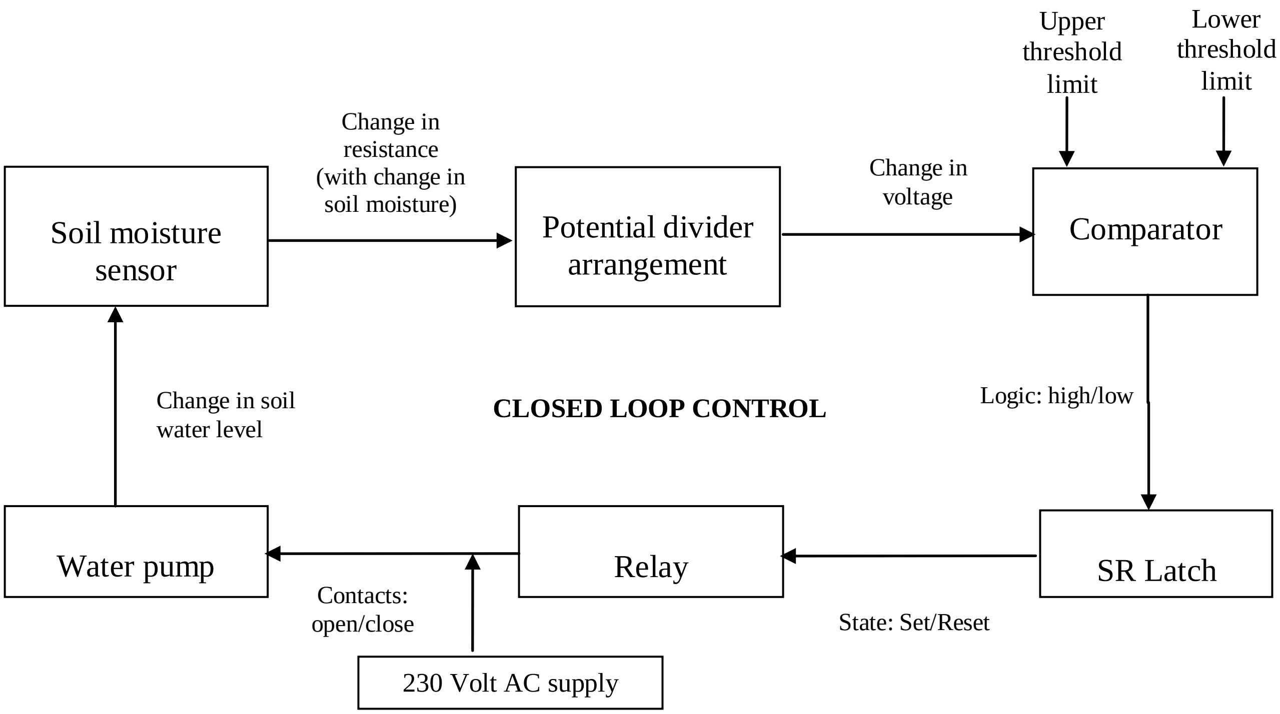


Figure 1: Block diagram of the system

1.2 Subsystems And Components

Table 1: List of components used

Sl.No.	Subsystem	Components	Specifications	Quantity
I	Sensor		Resistance block (gypsum)	1
II	Comparator	IC LM 358D		1
III	S-R Latch	IC 4011, 4049		1,1
IV	Amplifier	IC 741, potentiometer		1,1
V	Relay	Relay	12 volt DC	1
VI	Indicators	LEDs	Red, Blue, White	1,1,1
VII	Water pump	HJ-1000 model, submersible pump	220 V/50 Hz, 20 W, 1000l/h	1
VIII	Batteries	6F22	9 V	3

2. HARDWARE DESCRIPTION

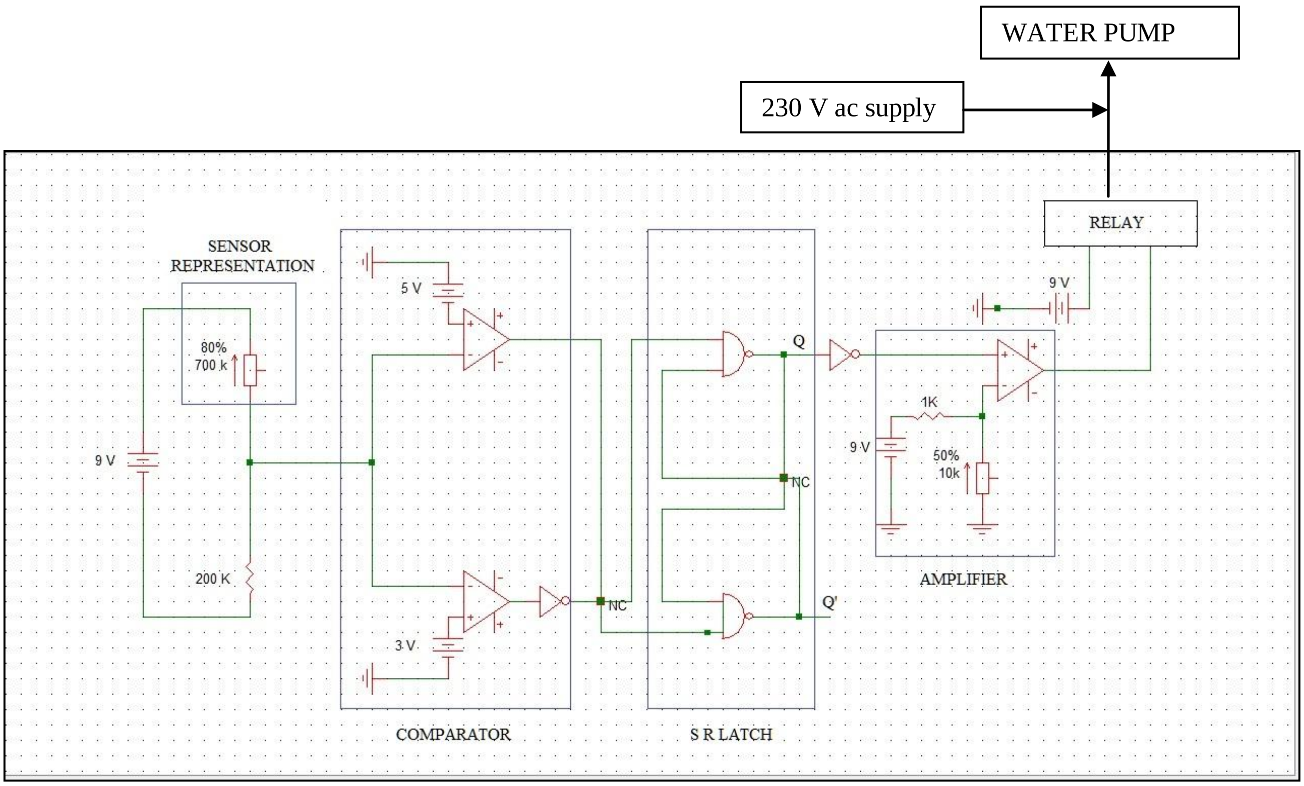


Figure 2 : Circuit schematic for hardware model showing various subsystems

2.1 Subsystem Description

I. SENSOR

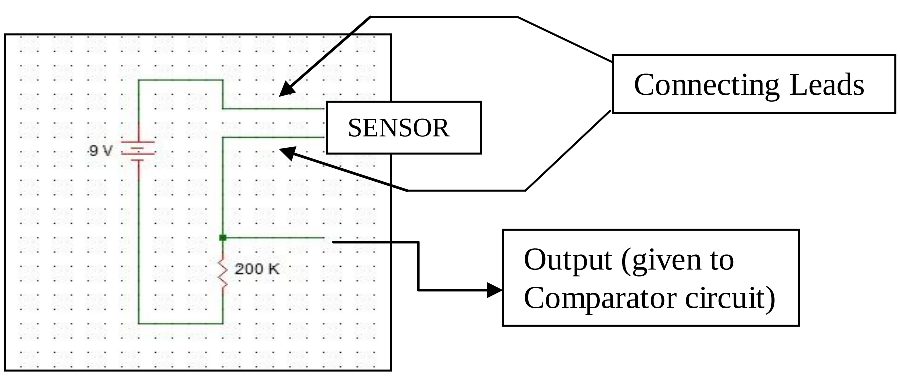


Figure 3: Sensor connected to form *potential divider arrangement* to provide a voltage output in relation to soil moisture levels

The parameter which is of importance is moisture content in the soil. A reliable indication of soil moisture levels is provided by electrical resistance blocks. These are a cost-effective tool for effective management of irrigation. They evaluate soil moisture tension by measuring the electrical resistance between the two electrodes emerging out of the block. The blocks absorb and release moisture as the soil wets and dries respectively. This electrical resistance is recorded with the help of a portable meter that is attached to the wire leads coming out from the moisture sensors. [1]

Instead of using commercially available sensors, effort has been made to build indigenous sensors with the objective to make the project cost effective. For this model, we have used gypsum for making the sensors.

The complete process for building the sensor has been outlined in

<u>Appendix A.</u>

Functional Description of Sensor:

1. For conversion of *change in resistance* to *change in voltage*, the sensor is connected with a 200 kΩ resistor in series to form a potential divider arrangement.

2. It gives a voltage output corresponding to the conductivity of the soil.

The conductivity of soil varies depending upon the amount of moisture present in it. It increases with increase in the water content of the soil. ***The higher the water content of the blocks, the lower the electrical resistance.***

3. The voltage output is taken from the *output terminal* of this circuit.

The moisture sensor is immersed into the specimen soil whose moisture content is under test.

The soil was examined under three conditions [2]

- **Dry condition:**

  The sensor is placed in the soil under dry conditions and embedded up to a fair depth of the soil. In dry condition, as there is no conduction path between the two copper leads the sensor gives a high resistance value (nearly 700 kΩ). The voltage output of the potential divider in this case ranges from 2.2 V to lower optimum level (3 V).

- **Optimum condition:**

  When water is added to the soil, it percolates through the successive layers of it and spreads across the layers of soil due to capillary force. This increases the moisture content of the soil. Thus a conductive path is established between the two copper leads. This leads to a decrease in resistance of sensor. The optimum condition of the soil can be set manually depending on the type of soil.

- **Excess wet condition:**

  With the increase in water content beyond the optimum level, there is drastic increase in the conductivity of the soil and the sensor resistance is further decreased to around 50 kΩ. The voltage output of the potential divider in this case ranges from upper optimum level (5 V) to 10 V.

II. COMPARATOR

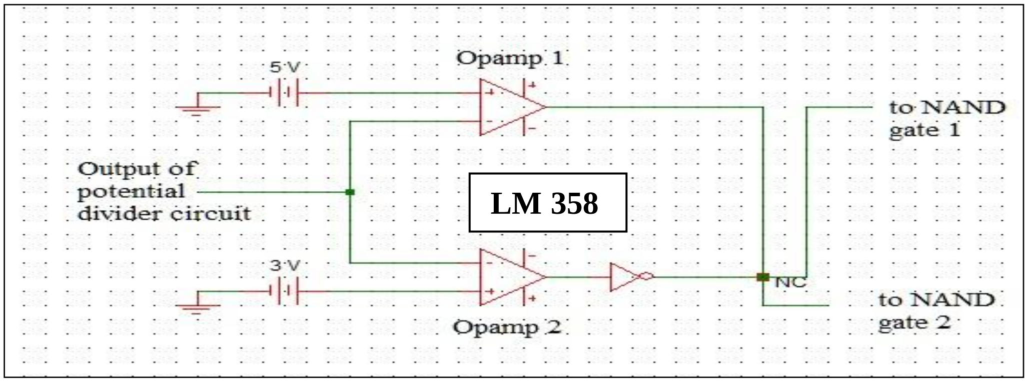


Figure 4: Comparator block

For the comparator circuit, we are using IC LM 358 which has two opamps. We have selected two thresholds: 5 V for logic high and 3 V for logic low. These two levels are set at the positive terminal of each opamp. The output of the potential divider is given to the negative terminals of the opamps. The two opamps are arranged such that when the output of the potential divider circuit falls below the preset value of lower opamp the lower opamp gives logic 0 and the upper opamp gives logic 1. When the output of potential divider circuit is in between range (5 V and 3V), then both opamps give logic 1 and when output of potential divider circuit is above the set value of upper opamp, then the upper opamp gives logic 0 and lower opamp gives logic 1. The output of the comparator circuit is fed into a SR Latch.

The various opamp outputs with varying soil conditions has been tabulated as below.

Table 2: Comparator logic

Sl No.	Range of voltage	Soil condition	Logic of Opamp 1 (upper)	Logic of Opamp 2 (lower)
1	> 5V	Excess wet	0	1
2	> 3V & < 5V	Optimum	1	1
3	< 3V	Dry	1	0

(**NOTE**: - Here upper preset level is taken as 5 V and lower preset level is taken as 3 V)

III. SR LATCH

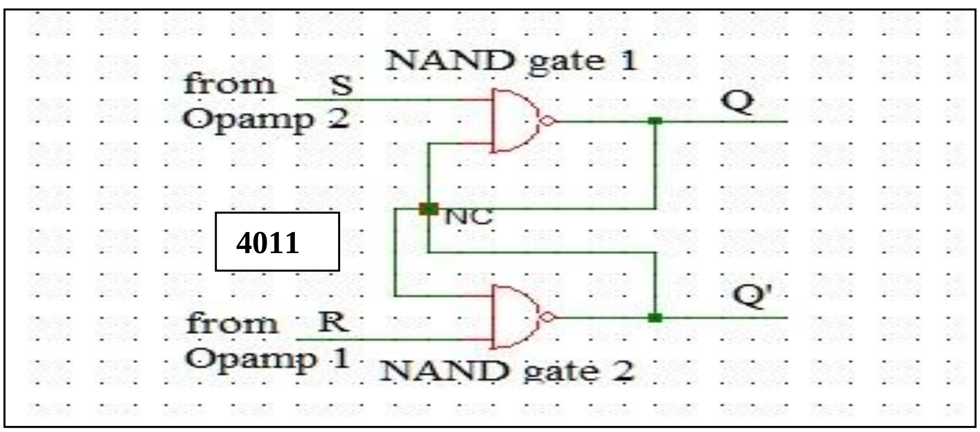


Figure 5: SR latch circuit

It is constructed using two NAND gates. Each gate has two outputs, *Q* and *Q'*, and two inputs, named *set* and *reset* respectively. This type of memory element is referred to as an *SR flip-flop* or *SR latch*. When Q=1 and Q'=0, it is in the *set state* (or 1-state). When Q=0 and Q'=1, it is in the *clear state* (or 0-state). The outputs Q and Q' are complements of each other and are named as the normal and complement outputs, respectively. The binary state of the flip-flop is taken to be the value of the normal output.

When the potential divider output is above higher level the flip flop output will be zero. When the potential divider output is in between two set levels the output of flip flop will not change. When the potential divider output is below lower level then output of flip flop will be 1.

The output of the latch for various soil conditions is tabulated below:

Table 3: SR latch logic

Sl. No.	Voltage range	Soil condition	S	R	Q	State	Q'
1	> 5V	Excess wet	1	0	0	Reset	1
2	> 3V & < 5V	Optimum	1	1	0	No change	1
			1	1	1		0
3	< 3V	Dry	0	1	1	Set	0

IV. **AMPLIFIER**

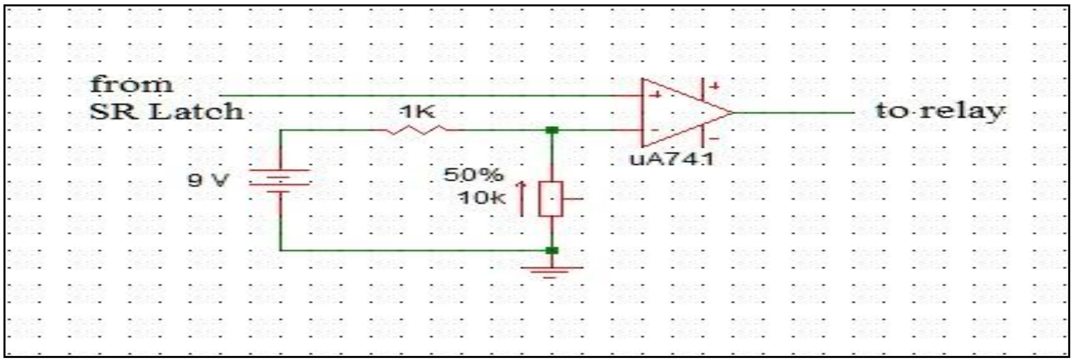


Figure 6: Amplifier circuit

Since the analog output voltage signal from the SR latch is not high enough to drive the relay, hence the need for amplification. The signal is amplified using a 741 opamp and then fed to the relay.

V. RELAY

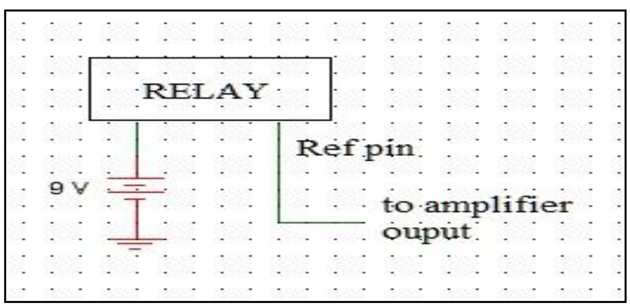


Figure 7: Relay pin connections

A relay is an electrical switch that opens and closes under the control of another electrical circuit. The output of flip flop is connected to a relay. The '*NO'* contact of the relay is connected with the power supply to water pump. When this relay will be on, then the water pump will start and when it is off then the power supply to water pump will be cut off and hence it stops.

The working of the relay for various test conditions is tabulated below.

Table 4: Operation of relay for various soil moisture conditions

Sl. No.	**Voltage range**	**Soil condition**	**Q**	**Amplifier output (digital)**	**Relay reference pin voltage**	**Relay 'NO' contact**	**Water pump operation**
1	> 5V	Excess wet	0	1	1	open	OFF
2	< 5V & > 3V	Optimally wet	0	1	1	open	OFF
		Optimally dry	1	0	0	closed	ON
3	< 3V	Dry	1	0	0	closed	ON

VI. INDICATORS

Three LEDs have been used for indication of the various soil conditions.

1. BLUE for indicating excess wet condition
2. RED for indicating dry condition
3. WHITE for indicating 'ON' condition of water pump

Table 5: LED and corresponding indication

Sl. No.	**Color of LED that glows**	**Indication**
1	Blue	Excess wet soil
2	Red	Dry soil
3	Blue + Red	Optimum soil water level
4	White	Water pump 'ON'

CHAPTER III: Methodology

1. Constructing the soil moisture sensor [1]

   Details are attached in Appendix A.

2. Setting the preset levels

   First, the voltage at minimum value of moisture and maximum value of moisture can be found out using a sensor and this will give an output in volts. These two voltage levels can be set as higher and lower levels at the opamps.

   In our model we have taken +5 V and +3 V as the upper and lower presets respectively.

3. Simulation of the circuit using MultiSim 11.0

   To test the correctness of the various logics we first implemented the entire system using software simulation. We used a variable resistance as a *representation of the senso*r. Varying this resistance as an indication of the varying moisture levels we simulated the schematic for three conditions: dry, optimum and excess water.

   The result of the simulation for each condition is shown below.

   After successful simulation we proceeded to hardware realization.

4. Hardware Implementation

   - Assembling the components:

     All the ICs were assembled on the breadboard according to the circuit layout. All connections were made.

- <u>Soldering:</u>

  After careful inspection of output at each component terminals, soldering was done.

- <u>Testing of Sensor:</u>

  The constructed sensor was embedded in the soil below a certain depth. Firstly, the testing was done for dry soil.

  Next sufficient water was added to check for wet soil conditions.

- <u>Connection of Water pump</u>

  The water pump is given supply directly from the mains 230v ac through the 'NO' contact of 12V DC relay. It acts as a switch for the Water pump circuit.

CHAPTER IV: Results

1. Simulation results using MultiSim:

By varying the resistance (700 kΩ) in the potential divider circuit as a representation for the dry/wet condition of the sample soil, the circuit was tested and the results are tabulated below:

Table 6: Simulation results

Sl No.	Soil Moisture level	Output of the sensor circuit (in Volts)	Output of the main pump controlling circuit (in Volts)
1	below lower level	2.375	0
2	increasing but below higher level	3.262	0
3	more than higher level	5.265	10
4	decreasing but higher than lower level	4.372	10

The simulation schematics are shown in figures below:

a) When the sensor senses low moisture

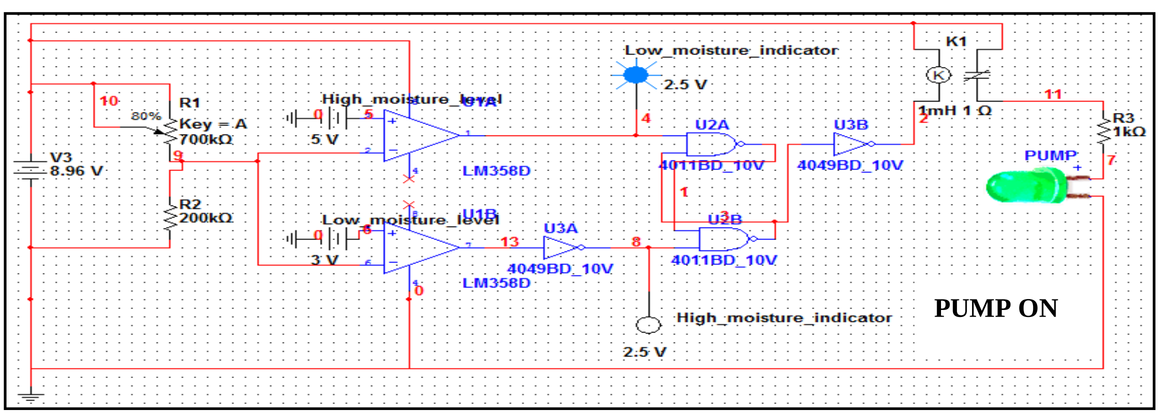


Figure 8: Circuit simulation snap for dry soil

b) When the sensor senses high moisture

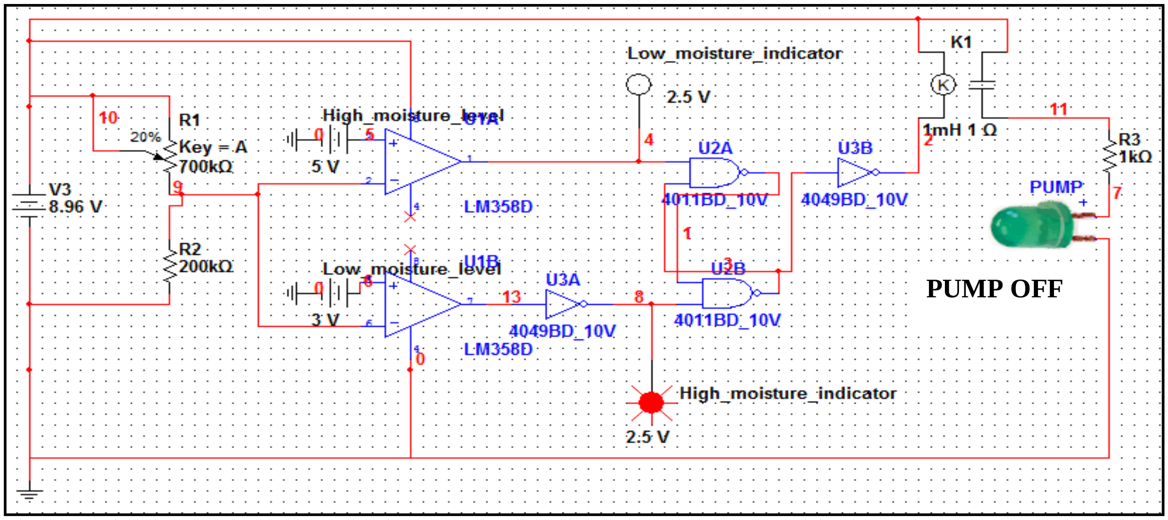


Figure 9: Circuit simulation snap for excess wet soil

2. Observations after Hardware Design:

By varying the dry/wet condition of the sample soil, the circuit was tested and the results are tabulated below:

Table 7: Results obtained after hardware implementation

Voltage from sensor output	Indication	Color of LED that glows	Action
Less than 3.06 V	Dry Soil	Red + White	Water pump ON
Greater than 4.53 V	Excess wet soil	Blue	Water pump OFF

CHAPTER V: Conclusion

A methodological approach has been followed in designing the opamp based system for measurement and control of the plant growth parameter, i.e. soil moisture. The results obtained from the measurement have shown that the system performance is quite reliable and accurate.

Field experience has shown that soil moisture sensors are very useful in diagnosing the changes needed and to fine-tune irrigation practices. Relatively minor regulations in irrigation practices can pay large dividends in terms of increased yields or water savings. The key to proper irrigation management using soil moisture sensors is regular monitoring of the sensors to track the soil moisture level and provide irrigation when the readings are in the determined range for the particular soil type. [4]

Thus, this system eliminates the drawbacks of the existing set-ups mentioned in the previous section. Also a cost analysis report has been prepared to compare the effective costs of the proposed model and microprocessor based system. Thus it has proved to be an easy to maintain, flexible and low cost solution.

COST ANALYSIS REPORT

- **Cost of project**

The approximate cost of project has been computed as below:

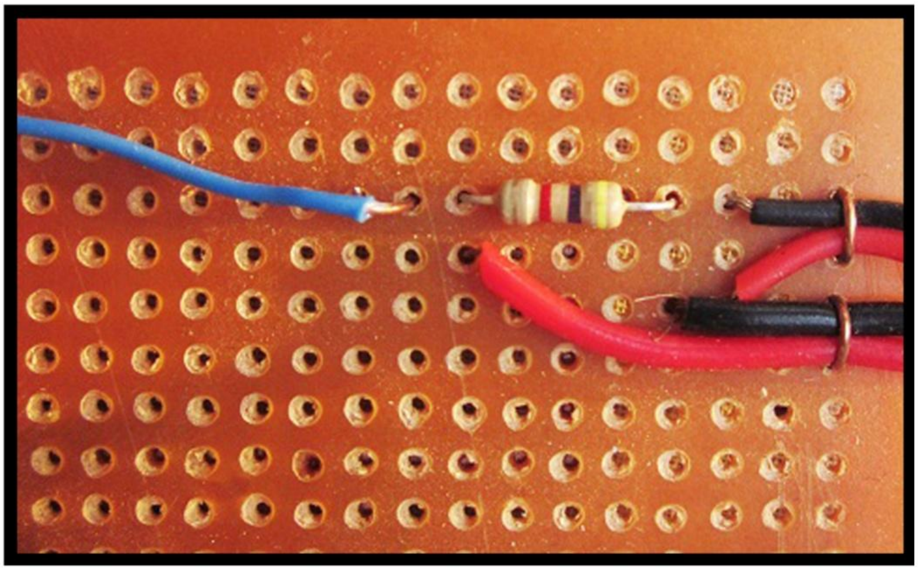
Sl. No.	**Component**	**Quantity**	**Amount (in Rs.)**
1	LM 358	1	10
2	4011	1	12
3	4049	1	12
4	Miscellaneous		20
5	Relay	1	14
6	Water pump	1	200
7	LEDs (red, blue, white)	1 + 1 + 1	2+2+2=6
		TOTAL (in Rs.)	274

Total cost of the project = Rs. 300 (approx.)

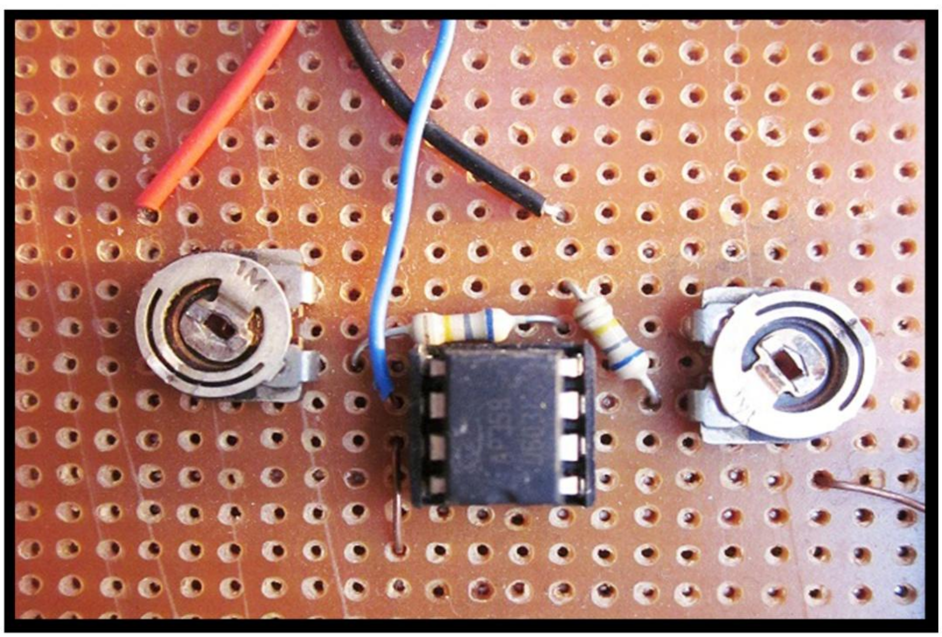
- Cost of soil moisture monitoring system based on microcontroller/ microprocessor (approx.)= Rs. 3000 [3]

Thus the cost of the proposed model is nearly **10 times less** compared to an equivalent embedded system based model.

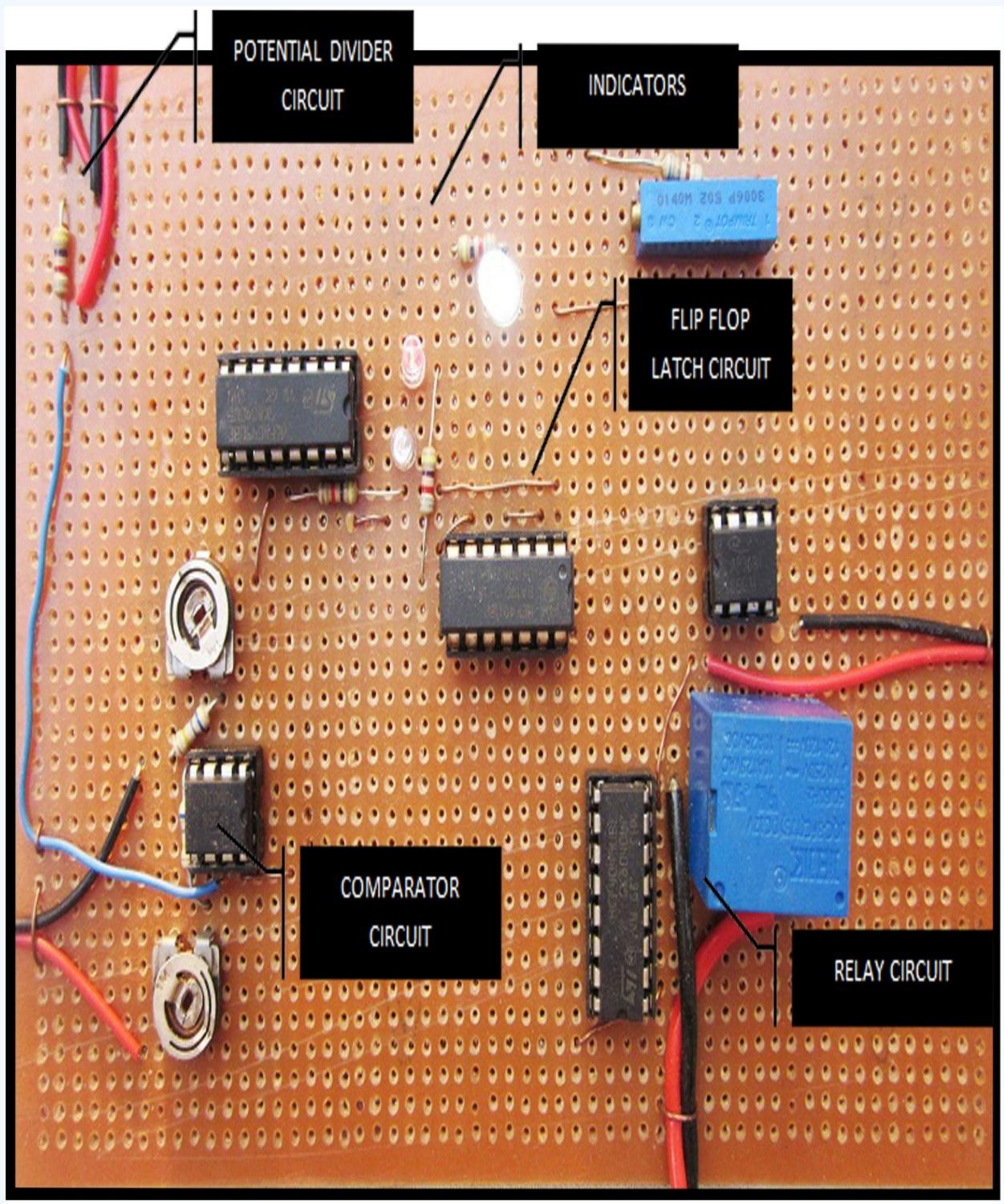
HARDWARE DESIGN SNAPS



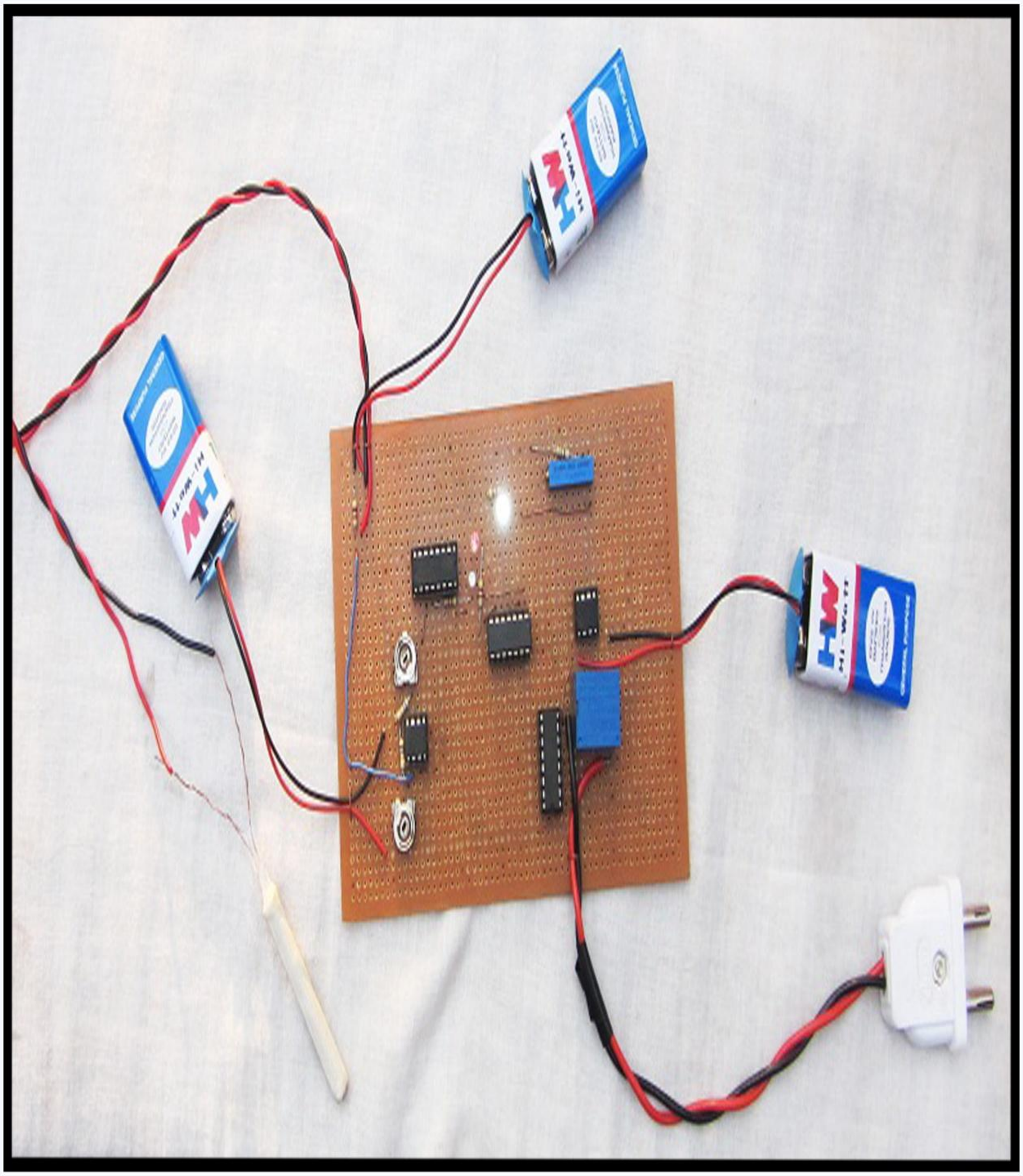
POTENTIAL DIVIDER CIRCUIT



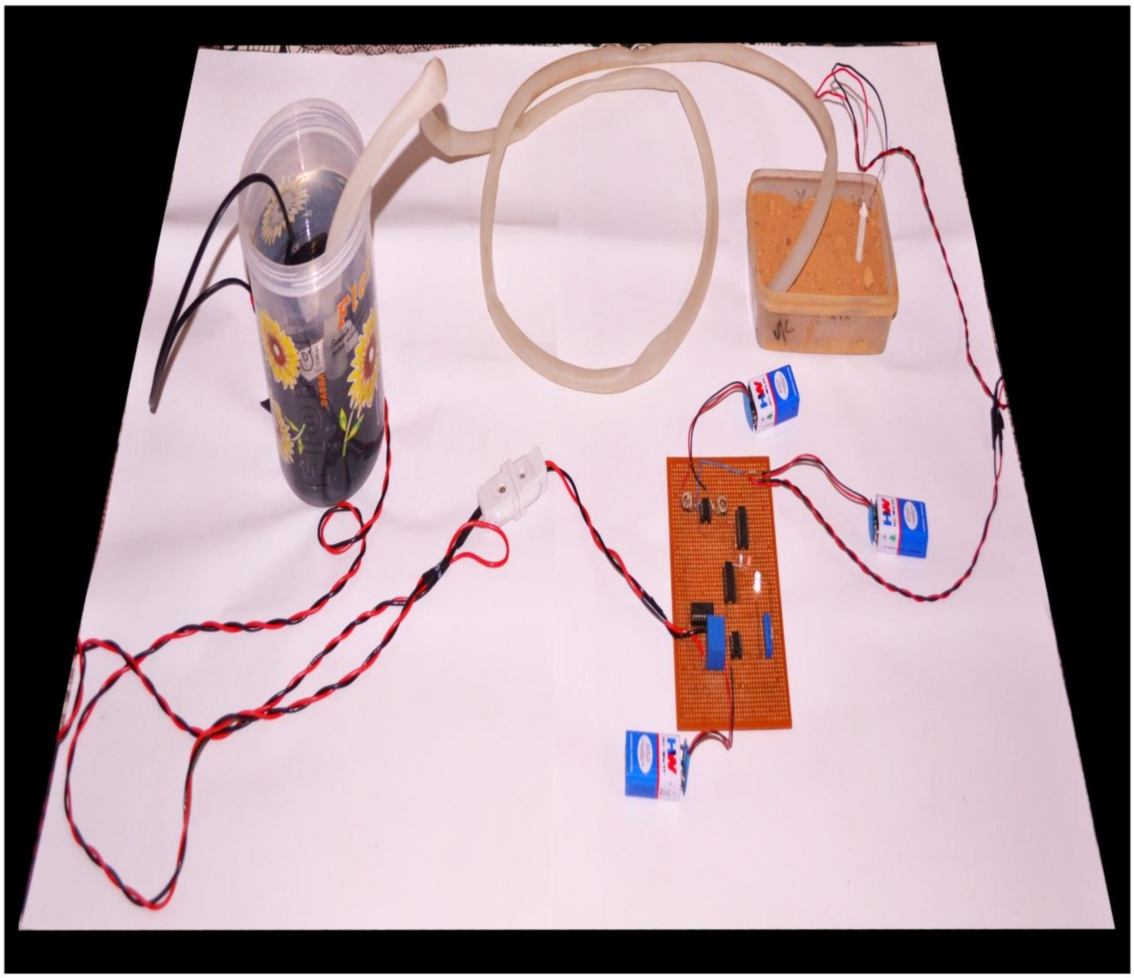
COMPARATOR CIRCUIT



DIFFERENT COMPONENTS OF THE CIRCUIT



CIRCUIT CONNECTION



EXPERIMENTAL SET-UP

REFERENCES

[1] Skinner. A., Hignett. C., and Dearden. J., "Resurrecting the Gypsum Block for Soil Moisture Measurement", Australian Viticulture, October/November 1997. (http://www.sowacs.com/sensors/gypsum.txt)

[2] Morris. M., "Soil Moisture Monitoring: Low Cost Tools and Methods" NCAT Energy Specialist, ATTRA Publication #IP277, 2006. (http://attra.ncat.org/attra-pub/PDF/soil_moisture.pdf)

[3] Daniel K. Fisher, Hirut Kebede, "A low-cost microcontroller-based system to monitor crop temperature and water status", Computers and Electronics in Agriculture *74 (2010)*

[4] Richard Allen, "Soil Water Monitoring with Inexpensive Equipment", University of Idaho, 2000 (www.kimberly.uidaho.edu/water/swm)

[5] IC Datasheets from www.datasheetcatalog.com

Appendix A

Procedure Followed To Make Soil Moisture Sensor:

This method includes taking two Copper wires and inserting them into a gypsum block and measuring the resistance between them. The gypsum absorbs the water and provides a decent range of resistance and moisture measurement.

Materials required:

1. Plaster of Paris
2. Cold water
3. Disposable cup for mixing
4. Wide straw
5. Two small pieces of copper wire (we used the single copper core of LAN cable wire which we are using for LAN connections)

Procedure:

1. The wires were straightened out perfectly by pliers. Then they were carefully positioned approximately 15 mm apart. For making multiple sensors, it is recommended to make them with the same gap to ensure consistency of measurements without having to individually calibrate each sensor.

2. Now the metal wires were inserted into the straw, ensuring that both are equally distant from the sides of the straw.

3. Plaster of Paris was prepared according to the instructions provided on the box. On our box it said mix two parts to one part cold water. We used a bamboo skewer to stir.

4. The mould was poured into the top of the straw. About one-fourth of the length was filled and then the probe was gently tapped to help the plaster settle between the gaps. The previous step was repeated until the straw was full.

5. The setting was allowed to stand for an hour.

6. After about an hour the bottom part of the sensor was removed carefully by cutting around the diameter of the bottom of the straw using a knife.

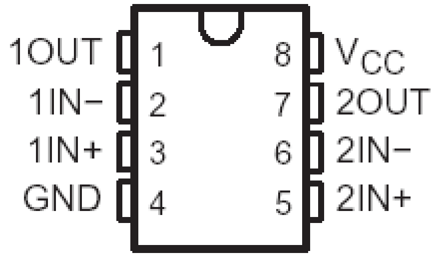
7. The plaster was allowed to dry for 24 hours before being tested.

8. The sensor was calibrated by getting a reading with the probe dry and then again when it is full saturated in water.

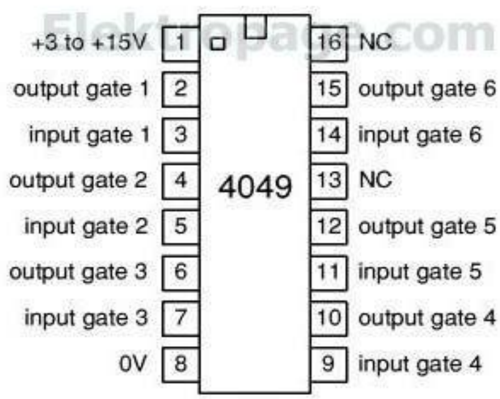
Appendix B

PIN DIAGRAMS OF VARIOUS ICs

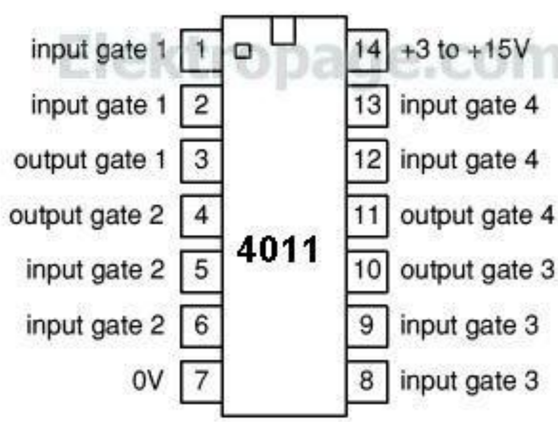
1. LM 358



2. 4049



3. 4011



Appendix C

IC DATASHEETS [5]

1. LM 358

National Semiconductor

October 2005

LM158/LM258/LM358/LM2904 Low Power Dual Operational Amplifiers

General Description

The LM158 series consists of two independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

Application areas include transducer amplifiers, dc gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM158 series can be directly operated off of the standard +5V power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional ±15V power supplies.

The LM358 and LM2904 are available in a chip sized package (8-Bump micro SMD) using National's micro SMD package technology.

Unique Characteristics

- In the linear mode the input common-mode voltage range includes ground and the output voltage can also swing to ground, even though operated from only a single power supply voltage.
- The unity gain cross frequency is temperature compensated.
- The input bias current is also temperature compensated.

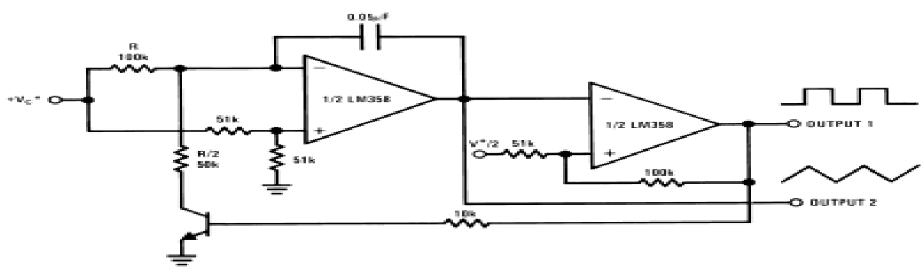
Advantages

- Two internally compensated op amps
- Eliminates need for dual supplies
- Allows direct sensing near GND and V_{OUT} also goes to GND
- Compatible with all forms of logic
- Power drain suitable for battery operation

Features

- Available in 8-Bump micro SMD chip sized package, (See AN-1112)
- Internally frequency compensated for unity gain
- Large dc voltage gain: 100 dB
- Wide bandwidth (unity gain): 1 MHz (temperature compensated)
- Wide power supply range:
  - — Single supply: 3V to 32V
  - — or dual supplies: ±1.5V to ±16V
- Very low supply current drain (500 µA) — essentially independent of supply voltage
- Low input offset voltage: 2 mV
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Large output voltage swing

Voltage Controlled Oscillator (VCO)



Absolute Maximum Ratings (Note 9)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

	LM158/LM258/LM358 LM158A/LM258A/LM358A	LM2904
Supply Voltage, V^+	32V	26V
Differential Input Voltage	32V	26V
Input Voltage	−0.3V to +32V	−0.3V to +26V
Power Dissipation (Note 1)		
Molded DIP	830 mW	830 mW
Metal Can	550 mW	
Small Outline Package (M)	530 mW	530 mW
micro SMD	435mW	
Output Short-Circuit to GND		
(One Amplifier) (Note 2)		
$V^+ \leq 15V$ and $T_A = 25°C$	Continuous	Continuous
Input Current ($V_{IN} < -0.3V$) (Note 3)	50 mA	50 mA
Operating Temperature Range		
LM358	0°C to +70°C	−40°C to +85°C
LM258	−25°C to +85°C	
LM158	−55°C to +125°C	
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C
Lead Temperature, DIP		
(Soldering, 10 seconds)	260°C	260°C
Lead Temperature, Metal Can		
(Soldering, 10 seconds)	300°C	300°C
Soldering Information		
Dual-In-Line Package		
Soldering (10 seconds)	260°C	260°C
Small Outline Package		
Vapor Phase (60 seconds)	215°C	215°C
Infrared (15 seconds)	220°C	220°C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

ESD Tolerance (Note 10)	250V	250V

Electrical Characteristics

$V^+ = +5.0V$, unless otherwise stated

Parameter	Conditions	LM158A			LM358A			LM158/LM258		
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Input Offset Voltage	(Note 5), $T_A = 25°C$		1	2		2	3		2	5
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$, $T_A = 25°C$, $V_{CM} = 0V$, (Note 6)		20	50		45	100		45	150
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, $V_{CM} = 0V$, $T_A = 25°C$		2	10		5	30		3	30
Input Common-Mode Voltage Range	$V^+ = 30V$, (Note 7) (LM2904, $V^+ = 26V$), $T_A = 25°C$	0		$V^+-1.5$	0		$V^+-1.5$	0		$V^+-1.5$
Supply Current	Over Full Temperature Range $R_L = \infty$ on All Op Amps									
	$V^+ = 30V$ (LM2904 $V^+ = 26V$)		1	2		1	2		1	2
	$V^+ = 5V$		0.5	1.2		0.5	1.2		0.5	1.2

2. CD 4011

October 1987
Revised January 1999

CD4001BC/CD4011BC
Quad 2-Input NOR Buffered B Series Gate • Quad 2-Input NAND Buffered B Series Gate

General Description

The CD4001BC and CD4011BC quad gates are monolithic complementary MOS (CMOS) integrated circuits constructed with N- and P-channel enhancement mode transistors. They have equal source and sink current capabilities and conform to standard B series output drive. The devices also have buffered outputs which improve transfer characteristics by providing very high gain.

All inputs are protected against static discharge with diodes to V_{DD} and V_{SS}.

Features

- Low power TTL:
  Fan out of 2 driving 74L compatibility: or 1 driving 74LS
- 5V–10V–15V parametric ratings
- Symmetrical output characteristics
- Maximum input leakage 1 µA at 15V over full temperature range

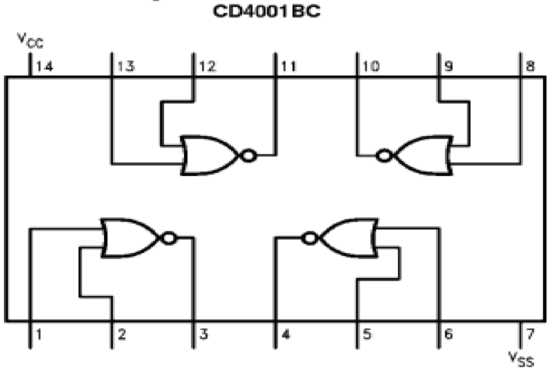
Ordering Code:

Order Number	Package Number	Package Description
CD4001BCM	M14A	14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-120, 0.150" Narrow
CD4001BCSJ	M14D	14-Lead Small Outline Package (SOP), EIAJ TYPE II, 5.3mm Wide
CD4001BCN	N14A	14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300" Wide
CD4011BCM	M14A	14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-120, 0.150" Narrow
CD4011BCN	N14A	14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300" Wide

Devices also available in Tape and Reel. Specify by appending the suffix letter "X" to the ordering code.

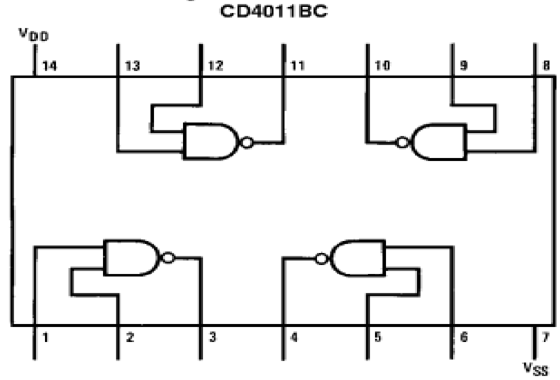
Connection Diagrams

Pin Assignments for DIP, SOIC and SOP
CD4001BC



Top View

Pin Assignments for DIP and SOIC
CD4011BC



Top View

3. CD 4049

National Semiconductor

March 1988

CD4049UBM/CD4049UBC Hex Inverting Buffer
CD4050BM/CD4050BC Hex Non-Inverting Buffer

General Description

These hex buffers are monolithic complementary MOS (CMOS) integrated circuits constructed with N- and P-channel enhancement mode transistors. These devices feature logic level conversion using only one supply voltage (V_{DD}). The input signal high level (V_{IH}) can exceed the V_{DD} supply voltage when these devices are used for logic level conversions. These devices are intended for use as hex buffers, CMOS to DTL/TTL converters, or as CMOS current drivers, and at V_{DD} = 5.0V, they can drive directly two DTL/TTL loads over the full operating temperature range.

Features

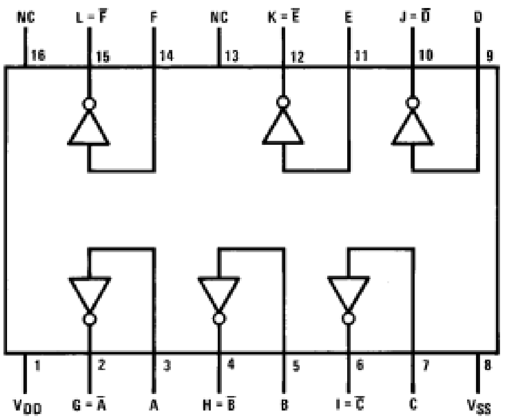
- Wide supply voltage range 3.0V to 15V
- Direct drive to 2 TTL loads at 5.0V over full temperature range
- High source and sink current capability
- Special input protection permits input voltages greater than V_{DD}

Applications

- CMOS hex inverter/buffer
- CMOS to DTL/TTL hex converter
- CMOS current "sink" or "source" driver
- CMOS high-to-low logic level converter

Connection Diagrams

CD4049UBM/CD4049UBC
Dual-In-Line Package

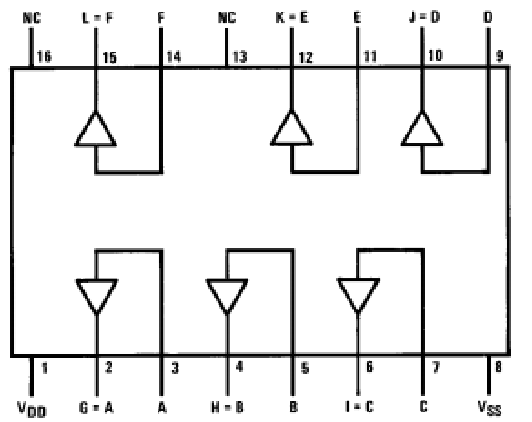


TL/F/5971–1

Top View

Order Number CD4049UB or CD4049B

CD4050BM/CD4050BC
Dual-In-Line Package



TL/F/5971–2

Top View

Order Number CD4050UB or CD4050B

Absolute Maximum Ratings (Notes 1 & 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage (V_{DD})	−0.5V to +18V
Input Voltage (V_{IN})	−0.5V to +18V
Voltage at Any Output Pin (V_{OUT})	−0.5V to V_{DD} + 0.5V
Storage Temperature Range (T_S)	−65°C to +150°C
Power Dissipation (P_D)	
Dual-In-Line	700 mW
Small Outline	500 mW
Lead Temperature (T_L)	
(Soldering, 10 seconds)	260°C

Recommended Operating Conditions (Note 2)

Supply Voltage (V_{DD})	3V to 15V
Input Voltage (V_{IN})	0V to 15V
Voltage at Any Output Pin (V_{OUT})	0 to V_{DD}
Operating Temperature Range (T_A)	
CD4049UBM, CD4050BM	−55°C to +125°C
CD4049UBC, CD4050BC	−40°C to +85°C

DC Electrical Characteristics CD4049M/CD4050BM (Note 2)

Symbol	Parameter	Conditions	−55°C		+25°C			+125°C		Units
			Min	Max	Min	Typ	Max	Min	Max	
I_{DD}	Quiescent Device Current	V_{DD} = 5V		1.0		0.01	1.0		30	μA
		V_{DD} = 10V		2.0		0.01	2.0		60	μA
		V_{DD} = 15V		4.0		0.03	4.0		120	μA
V_{OL}	Low Level Output Voltage	V_{IH} = V_{DD}, V_{IL} = 0V, $\|I_O\|$ < 1 μA								
		V_{DD} = 5V		0.05		0	0.05		0.05	V
		V_{DD} = 10V		0.05		0	0.05		0.05	V
		V_{DD} = 15V		0.05		0	0.05		0.05	V
V_{OH}	High Level Output Voltage	V_{IH} = V_{DD}, V_{IL} = 0V, $\|I_O\|$ < 1 μA								
		V_{DD} = 5V	4.95		4.95	5		4.95		V
		V_{DD} = 10V	9.95		9.95	10		9.95		V
		V_{DD} = 15V	14.95		14.95	15		14.95		V
V_{IL}	Low Level Input Voltage (CD4050BM Only)	$\|I_O\|$ < 1 μA								
		V_{DD} = 5V, V_O = 0.5V		1.5		2.25	1.5		1.5	V
		V_{DD} = 10V, V_O = 1V		3.0		4.5	3.0		3.0	V
		V_{DD} = 15V, V_O = 1.5V		4.0		6.75	4.0		4.0	V
V_{IL}	Low Level Input Voltage (CD4049UBM Only)	$\|I_O\|$ < 1 μA								
		V_{DD} = 5V, V_O = 4.5V		1.0		1.5	1.0		1.0	V
		V_{DD} = 10V, V_O = 9V		2.0		2.5	2.0		2.0	V
		V_{DD} = 15V, V_O = 13.5V		3.0		3.5	3.0		3.0	V
V_{IH}	High Level Input Voltage (CD4050BM Only)	$\|I_O\|$ < 1 μA								
		V_{DD} = 5V, V_O = 4.5V	3.5		3.5	2.75		3.5		V
		V_{DD} = 10V, V_O = 9V	7.0		7.0	5.5		7.0		V
		V_{DD} = 15V, V_O = 13.5V	11.0		11.0	8.25		11.0		V
V_{IH}	High Level Input Voltage (CD4049UBM Only)	$\|I_O\|$ < 1 μA								
		V_{DD} = 5V, V_O = 0.5V	4.0		4.0	3.5		4.0		V
		V_{DD} = 10V, V_O = 1V	8.0		8.0	7.5		8.0		V
		V_{DD} = 15V, V_O = 1.5V	12.0		12.0	11.5		12.0		V
I_{OL}	Low Level Output Current (Note 3)	V_{IH} = V_{DD}, V_{IL} = 0V								
		V_{DD} = 5V, V_O = 0.4V	5.6		4.6	5		3.2		mA
		V_{DD} = 10V, V_O = 0.5V	12		9.8	12		6.8		mA
		V_{DD} = 15V, V_O = 1.5V	35		29	40		20		mA

Note 1: "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed; they are not meant to imply that the devices should be operated at these limits. The table of "Recommended Operating Conditions" and "Electrical Characteristics" provides conditions for actual device operation.

Note 2: V_{SS} = 0V unless otherwise specified.

Note 3: These are *peak* output current capabilities. Continuous output current is rated at 12 mA maximum. The output current should not be allowed to exceed this value for extended periods of time. I_{OL} and I_{OH} are tested one output at a time.

DC Electrical Characteristics CD4049UBC/CD4050BC (Note 2) (Continued)

Symbol	Parameter	Conditions	−40°C		+25°C			+85°C		Units
			Min	Max	Min	Typ	Max	Min	Max	
I_{OL}	Low Level Output Current (Note 3)	$V_{IH} = V_{DD}$, $V_{IL} = 0V$								
		$V_{DD} = 5V$, $V_O = 0.4V$	4.6		4.0	5		3.2		mA
		$V_{DD} = 10V$, $V_O = 0.5V$	9.8		8.5	12		6.8		mA
		$V_{DD} = 15V$, $V_O = 1.5V$	29		25	40		20		mA
I_{OH}	High Level Output Current (Note 3)	$V_{IH} = V_{DD}$, $V_{IL} = 0V$								
		$V_{DD} = 5V$, $V_O = 4.6V$	−1.0		−0.9	−1.6		−0.72		mA
		$V_{DD} = 10V$, $V_O = 9.5V$	−2.1		−1.9	−3.6		−1.5		mA
		$V_{DD} = 15V$, $V_O = 13.5V$	−7.1		−6.2	−12		−5		mA
I_{IN}	Input Current	$V_{DD} = 15V$, $V_{IN} = 0V$	−0.3		−0.3	-10^{-5}			−1.0	μA
		$V_{DD} = 15V$, $V_{IN} = 15V$	0.3		0.3	10^{-5}			1.0	μA

AC Electrical Characteristics* CD4049UBM/CD4049UBC

$T_A = 25°C$, $C_L = 50$ pF, $R_L = 200k$, $t_r = t_f = 20$ ns, unless otherwise specified

Symbol	Parameter	Conditions	Min	Typ	Max	Units
t_{PHL}	Propagation Delay Time High-to-Low Level	$V_{DD} = 5V$		30	65	ns
		$V_{DD} = 10V$		20	40	ns
		$V_{DD} = 15V$		15	30	ns
t_{PLH}	Propagation Delay Time Low-to-High Level	$V_{DD} = 5V$		45	85	ns
		$V_{DD} = 10V$		25	45	ns
		$V_{DD} = 15V$		20	35	ns
t_{THL}	Transition Time High-to-Low Level	$V_{DD} = 5V$		30	60	ns
		$V_{DD} = 10V$		20	40	ns
		$V_{DD} = 15V$		15	30	ns
t_{TLH}	Transition Time Low-to-High Level	$V_{DD} = 5V$		60	120	ns
		$V_{DD} = 10V$		30	55	ns
		$V_{DD} = 15V$		25	45	ns
C_{IN}	Input Capacitance	Any Input		15	22.5	pF

*AC Parameters are guaranteed by DC correlated testing.

AC Electrical Characteristics* CD4050BM/CD4050BC

$T_A = 25°C$, $C_L = 50$ pF, $R_L = 200k$, $t_r = t_f = 20$ ns, unless otherwise specified

Symbol	Parameter	Conditions	Min	Typ	Max	Units
t_{PHL}	Propagation Delay Time High-to-Low Level	$V_{DD} = 5V$		60	110	ns
		$V_{DD} = 10V$		25	55	ns
		$V_{DD} = 15V$		20	30	ns
t_{PLH}	Propagation Delay Time Low-to-High Level	$V_{DD} = 5V$		60	120	ns
		$V_{DD} = 10V$		30	55	ns
		$V_{DD} = 15V$		25	45	ns
t_{THL}	Transition Time High-to-Low Level	$V_{DD} = 5V$		30	60	ns
		$V_{DD} = 10V$		20	40	ns
		$V_{DD} = 15V$		15	30	ns
t_{TLH}	Transition Time	$V_{DD} = 5V$		60	120	ns